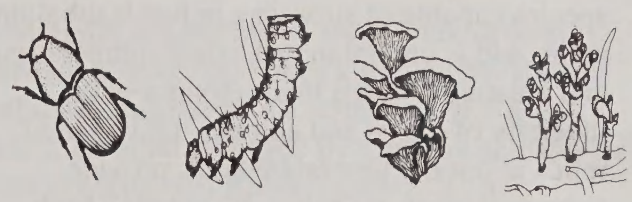
Forest Health Protection



Report 11-03

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HEALTH OF WHITEBARK PINE FORESTS AFTER MOUNTAIN PINE BEETLE OUTBREAKS

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ABSTRACT

Whitebark pine (*Pinus albicaulis*), a keystone high-elevation species, is currently at risk due to a combination of white pine blister rust (WPBR) (*Cronartium ribicola*), forest succession, and outbreaks of mountain pine beetle (MPB) (*Dendroctonus ponderosae).* While recent mortality is often quantified by aerial detection surveys (ADS) or ground surveys, little information is presented to describe what stands look like following MPB outbreaks. This information may help prioritize areas for restoration. In 2008 and 2009, the severity of MPB impacts was measured in 42 whitebark pine stands in Idaho, Montana, and Wyoming. WPBR was recorded on remaining live, mature whitebark pine and whitebark pine regeneration. Probable stand trajectory was determined by comparing abundance and health of remaining whitebark pine with other competing tree species. During the recent outbreak, 30 to 97 percent of whitebark pine basal area tallied within each stand was killed by MPB. The density of live whitebark pine dropped by more than 80 percent on over half of areas surveyed. WPBR infection levels on remaining live, mature whitebark pine averaged 64 percent in northern Idaho, western Montana, and the Greater Yellowstone Area (GYA) (southwestern Montana, eastern Idaho, and northwest Wyoming) but only 4 percent in drier central Idaho. Infection levels on whitebark pine regeneration ranged from 0 to 81 percent. Regeneration of other tree species, primarily subalpine fir (*Abies lasiocarpa*), outnumbered whitebark pine in 69 percent of areas. Based on WPBR and MPB impacts on whitebark pine and abundance of other tree species, at least 57 percent of sites surveyed will likely convert from whitebark pine to other cover types without restoration efforts or wildfire. In central Idaho, current outbreak losses were compared to losses from an outbreak that occurred circa the 1930s. In four of six stands attacked in both periods, more whitebark pine basal area was killed in the 1930s.

INTRODUCTION

Whitebark pine (*Pinus albicaulis*) is a keystone species of high elevation ecosystems throughout western North America. It is often the only tree

species capable of surviving in harsh subalpine areas, and is crucial in watershed stabilization and creating habitats that support a wide diversity of plants and animals. Old gnarled relics in remote timberline areas provide important aesthetic values by creating high elevation vistas and providing much of the character of the alpine experience (Schwandt 2006, Tomback and others 2001).

Whitebark pine is currently at risk in much of its natural range due to a combination of white pine blister rust (WPBR, *Cronartium ribicola*) (an introduced disease)(fig. 1); successional replacement by shade tolerant species (fig. 2), and recent outbreaks of mountain pine beetle (MPB, *Dendroctonus ponderosae*) (Keane and others 2002, Gibson and others 2008). Although MPB outbreaks have occurred historically in whitebark pine causing severe losses of mature trees, the additional impacts of WPBR on regeneration and cone production have caused population declines far exceeding previous levels resulting in local extirpation of some populations and threatened extinction of others (Schwandt 2006).

Figure 1. Whitebark pine regeneration infected with white pine blister rust.

Figure 2. Subalpine fir becoming dominant cover type as whitebark pine is killed by mountain pine beetle at Kings Hill, Lewis & Clark National Forest, Montana.

Aerial detection surveys (ADS) have documented recent increases in MPB activity in the Northern Rockies (Gibson 2004), but coverage has not always been complete or consistent. In addition, surveys only record recent mortality, so cumulative mortality is not known if areas are not flown annually. Even where annual mortality levels have been reported, ADS does not document WPBR infection levels or the amount of live whitebark pine remaining to provide regeneration. Since whitebark pine depends almost exclusively on the Clark's nutcracker (*Nucifraga Columbiana*) for natural regeneration (Tomback and Linhart 1990), the loss of most mature whitebark pines in a stand may result in little to no regeneration if there are too few cone-bearing trees to support a nutcracker population (McKinney and others 2009).

There have been many reports documenting MPB mortality in lodgepole and whitebark pine stands during MPB outbreaks (Kegley and others 2001, 2004; Gibson 2004, 2005, 2007; Gibson and Aquino 2006; Gibson and others 2008, Macfarlane and others 2010), but these have usually been limited in scope, conducted before the outbreak has run its course, or have not always looked at competing vegetation or regeneration. Recent MPB outbreaks have received a great deal of attention (Gibson 2004, Logan and Powell 2001) and have been prevalent

across much of the whitebark pine range – especially in the Northern Rockies. However, little information is presented to describe what the stands look like following MPB outbreaks except to claim the future prognosis for whitebark pine is bleak (Tomback and others 2001).

We investigated this information gap by documenting the condition of regeneration and remaining live, mature trees in various stand types following MPB outbreaks (fig. 3). We hope this information will help resource managers better understand losses from a combination of insect and disease agents and provide information that will assist in developing and prioritizing restoration activities.

The primary goal of this project was to obtain information that could be used to make recommendations and set priorities regarding restoration of whitebark pine in the Northern Rockies. Specific objectives to meet this goal were to:

1. determine the severity of MPB impacts in whitebark pine stands following outbreaks and to quantify both dead and remaining live, mature whitebark pine
2. determine WPBR status of remaining mature, live whitebark pine
3. determine WPBR infection levels in whitebark pine regeneration
4. determine probable stand trajectory by recording health and abundance of other tree species in mixed stands

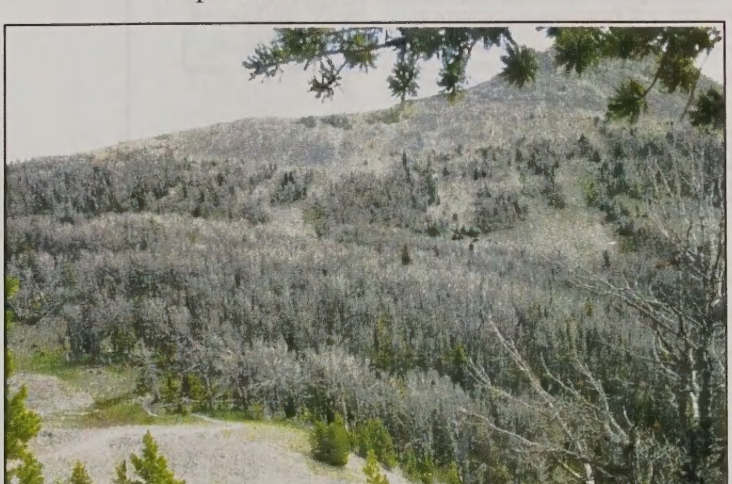

Figure 3. Stand evaluated near Avalanche Peak in Yellowstone National Park with 93% whitebark pine mortality following a recent mountain pine beetle outbreak.

In semiarid central Idaho, there were several stands where skeletal trees killed by MPB in an outbreak circa the 1930s remained on site and were quantified and aged by tree ring analysis in 1998 (Perkins and Roberts 2003). This presented an opportunity to compare current outbreak losses with losses from the earlier outbreak (fig. 4).

Figure 4. Current mountain pine beetle killed trees with red needles (circle) compared to trees killed during the 1930s outbreak (pentagon) on Poverty Flat near Clayton in central Idaho. Trees killed during the 1930s outbreak are visible throughout the photo as gray snags with no fine limbs.

METHODS

Forests in Idaho, Montana, and Yellowstone National Park (YNP) in Wyoming where recent MPB outbreaks have occurred in whitebark pine were identified from past ADS, local specialists, or other surveys. Within these forests, we selected 42 stands on National Forest, Bureau of Land Management, YNP, and private lands. These stands were accessible by road or within reasonable hiking distance and had several years of MPB-caused tree mortality (fig. 5). Stands were sampled using variable-radius plots for large trees and fixed-radius plots for regeneration. Plots were taken at a frequency that adequately sampled selected stands. From plot center, a 10 or 20 basal area factor (BAF) prism was used to select sample trees greater than five

inches diameter at breast height (dbh). BAF was chosen to get an average of 8 to 10 trees per plot. The same BAF was used for all plots in a given stand. Data collected for each tree included tree species, dbh, condition, and damage code (mortality causes and WPBR severity levels for live trees). Stand information included GPS coordinates, slope, aspect, elevation, and slope position. All trees less than five inches dbh and greater than six inches in height were tallied in a 1/300th acre regeneration subplot (radius = 6.8') at plot center of each variable-radius plot. Regeneration included seedlings and saplings from six inches tall to 4.9 inches dbh.

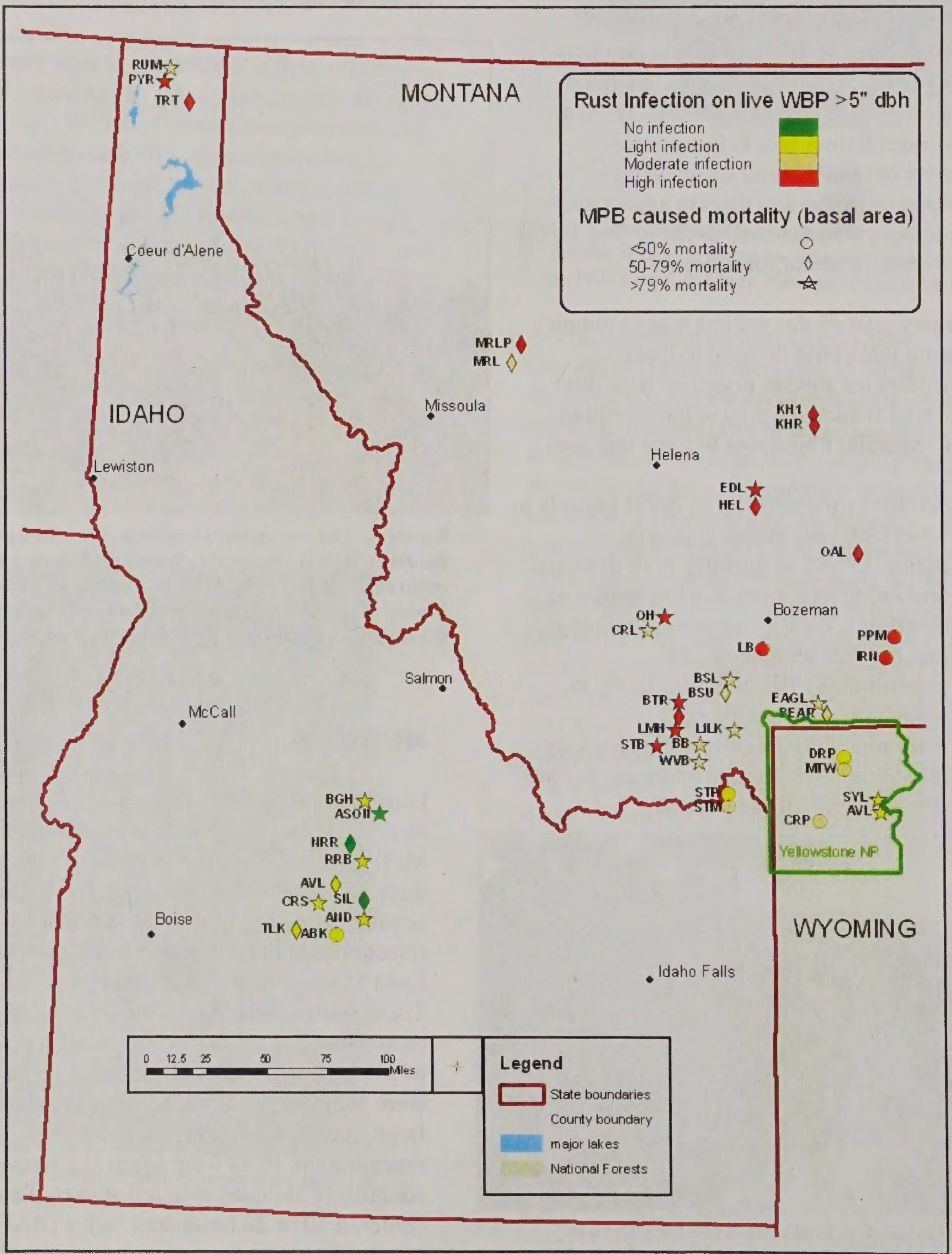

Figure 5. Locations of 42 whitebark pine (WBP) stands surveyed in Idaho, Montana, and Wyoming with white pine blister rust infection levels and mountain pine beetle (MPB) caused mortality.

Survey data were entered into a spreadsheet and analyzed using the **F**orest **In**sect and **Di**sease **T**ally (FINDIT) program (Bentz 2000). The following statistics were calculated for each stand:

1. Total trees/acre (TPA) by species
2. Total live and dead basal area (BA ft^2/ac)
3. Quadratic mean diameter (QMD) of live trees by species
4. Live stand density index (SDI)
5. Number of dead and live trees
6. Percentage TPA of each tree species
7. Percentage BA of each tree species
8. Percentage of BA killed by damaging agents in 2009, 2008, and mortality older than 2008
9. TPA by species in $1/300^{th}$ acre regeneration plots

Multiple linear regression analysis and ANOVA were used to examine relationships between slope, elevation, and aspect with basal area killed by MPB and amount of WPBR infection. We also analyzed differences in MPB and WPBR impacts and tree composition by geographical locations.

In central Idaho, whitebark pine BA lost in the current MPB outbreak was compared to BA lost in the 1930s outbreak.

RESULTS

Mountain Pine Beetle Mortality

Mortality from MPB in the 42 stands surveyed ranged from 30 to 97 percent (mean 72 percent) of whitebark pine BA (fig. 6). Over 90 percent mortality occurred in eight stands in the following locations: Sawtooth National Recreation Area (SNRA) in central Idaho, Beaverhead-Deerlodge National Forests in the Tobacco Roots and Gravelly Ranges, Helena National Forest in western Montana, Idaho Panhandle National Forests in northern Idaho, and YNP in Wyoming (highlighted in red in table 1).

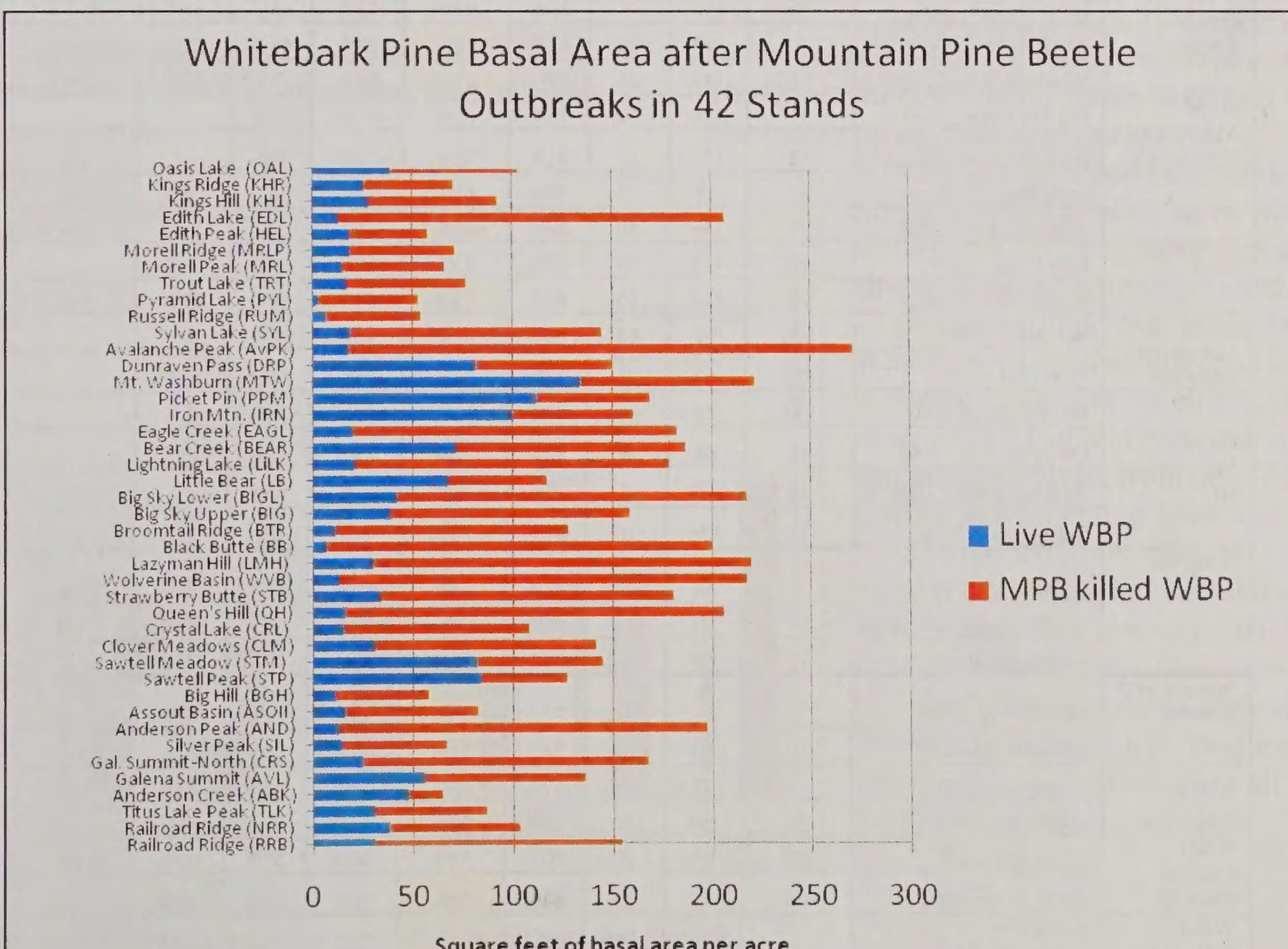

Figure 6. Basal area of live and mountain pine beetle killed whitebark pine by stand.

Table 1. Whitebark pine (WBP) stand characteristics used to predict cover type conversion risk with critical levels highlighted (see discussion for color coding definitions). These characteristics include WBP BA killed by mountain pine beetle (WBP BA dead, % WBP BA killed) and white pine blister rust (WPBR) infection levels on live, mature WBP and WBP < 5 inches dbh.

Region/ Area	Stand/Year surveyed	WBP BA Live (ft^2/acre)	WBP BA dead	Other spp. BA	% WBP BA killed	% WBP after outbreak	% WPBR on live mature WBP	WBP <5" % of total TPA	% WPBR on WBP <5"	**High Risk to convert to other cover type**
Central ID/ Sawtooth NRA	Railroad Ridge *2008*	31	124	3	80%	91%	6%	100%		
	Railroad Ridge *2008*	38	65	9	63%	81%	0%	15%	5%	
	Titus Lake Peak *2008*	31	56	26	64%	54%	5%	34%		
	Anderson Creek *2008*	48	17	14	26%	77%	1%	71%	0%	
	Galena Summit *2008*	56	80	30	59%	65%	3%	44%		
	Galena Sum-North *2008*	25	143	6	85%	81%	3%	32%	0%	
	Silver Peak 2008	**14**	53	20	79%	41%	0%	72%		
	Anderson Peak *2008*	13	184	14	93%	48%	10%	21%		**yes**
Central ID/ Salmon-Challis NF	Assout Basin *2008*	16	67	2	81%	89%	0%	70%	2%	
	Big Hill *2008*	11	47	2	81%	85%	16%	89%		
GYA/ Targhee NF	Sawtell Peak *2008*	84	43	51	34%	62%	29%	27%		
	Sawtell Meadow *2008*	82	63	41	43%	67%	53%	14%		
GYA/ BVRD NF-Tobacco Roots	Clover Meadows *2008*	31	111	4	78%	89%	84%	48%	27%	**yes**
	Crystal Lake *2009*	15	93	48	86%	24%	65%	13%		**yes**
	Queen's Hill *2009*	16	190	12	92%	57%	76%	74%	55%	**yes**
GYA/ BVRD NF-Gravelly Range	Strawberry Butte *2009*	34	147	17	81%	67%	77%	100%	61%	**yes**
	Wolverine Basin *2009*	13	205	34	94%	28%	55%	20%		**yes**
	Lazyman Hill *2009*	30	190	7	86%	81%	72%	66%	16%	
	Black Butte *2009*	7	193	10	97%	41%	58%	68%	21%	**yes**
	Broomtail Ridge *2009*	11	117	36	91%	23%	94%	3%	81%	**yes**
GYA/ Yellowstone Club (private)	Big Sky Upper *2009*	39	120	19	75%	67%	41%	29%		
	Big Sky Lower 2009	42	176	16	81%	72%	53%	8%		**yes**
GYA/ Gallatin NF - West	Little Bear *2009*	68	49	33	42%	67%	78%	36%	33%	**yes**
	Lightning Lake *2009*	21	158	40	88%	34%	38%	8%	21%	**yes**
	Bear Creek *2009*	72	115	15	61%	83%	60%	24%	21%	
	Eagle Creek *2009*	20	163	66	89%	23%	64%	14%	27%	**yes**
GYA/ Gallatin NF-Beartooth	Iron Mtn. *2009*	100	61	63	38%	61%	71%	7%		
	Picket Pin *2009*	112	57	24	34%	82%	73%	95%	11%	
GYA/ Yellowstone NP	Mt. Washburn *2008*	134	88	38	40%	78%	43%	26%		
	Dunraven Pass *2008*	82	68	8	45%	91%	28%	40%		
	Avalanche Peak *2009*	18	253	8	93%	69%	13%	81%	4%	**yes**
	Sylvan Lake *2009*	19	126	26	87%	42%	19%	0%	24%	**yes**
North ID/ IPNF	Russell Ridge *2008*	7	48	43	87%	14%	60%	14%	15%	**yes**
	Pyramid Lake *2008-09*	3	50	121	94%	2%	77%	2%	23%	**yes**
	Trout Lake *2009*	17	60	64	78%	21%	89%	19%	23%	**yes**
Western MT/ Lolo NF	Morell Peak *2008*	15	51	23	77%	39%	54%	18%	6%	**yes**
	Morell Ridge *2008*	19	53	36	74%	35%	79%	5%		**yes**
W MT/ Helena NF	Edith Peak *2008*	19	39	103	67%	16%	75%	45%	31%	**yes**
	Edith Lake *2008*	13	194	30	94%	30%	100%	88%	16%	**yes**
W MT/ Lewis & Clark NF	Kings Hill *2008*	28	65	20	70%	58%	89%	57%	22%	**yes**
	Kings Ridge *2008*	26	45	47	63%	36%	90%	21%	68%	**yes**
W MT/ Gallatin NF	Crazy Mtns Oasis Lake *2009*	39	64	110	62%	26%	97%	7%	27%	**yes**

Whitebark pine density (BA) was reduced by more than 80 percent on over half of stands surveyed. Over 50 percent of whitebark pine BA was lost on 81 percent of stands and 76 percent of sites currently have less than 50 ft^2/acre of live whitebark pine BA remaining. Although stands were purposely selected where the MPB outbreak had peaked, a few stands contained current beetle attacks so losses in these stands are likely to increase.

We found no statistically significant relationships between geographic area, slope, elevation, or aspect and basal area killed by MPB.

1930s outbreak compared to current outbreak
Of six stands in central Idaho where MPB outbreaks occurred in both the 1930s and 2000s time periods, three had significantly more BA killed in the 1930s, two had approximately the same amount of BA killed during both periods, and one had more BA killed in the current outbreak (fig. 7). For *some* susceptible stands in central Idaho, this provides evidence that whitebark pine mortality during the 1930s MPB outbreak was as great as, or greater than, current mortality levels.

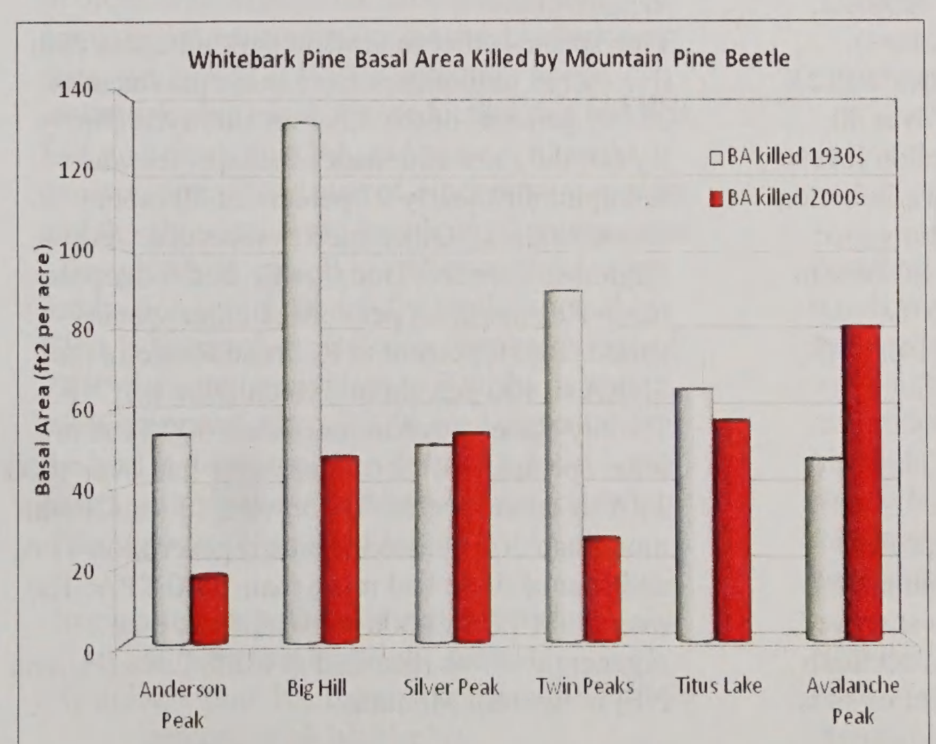

Figure 7. Whitebark pine basal area killed in current and historic outbreaks in 6 stands in central Idaho.

White Pine Blister Rust

Infection on Live, Mature Whitebark Pine
There were a total of 2,473 whitebark pine tallied, and slightly more than half were infected with WPBR. However, only 10 percent of all trees had severe infections with top kill that would affect cone production. Most infections (54 percent) tallied were branch cankers, and severity was light.

There was a significant negative correlation between percent of trees infected with WPBR and elevation ($p<.001$); infection levels increased as elevation declined. There were no statistically significant relationships between WPBR infection level and either slope or aspect.

WPBR infection levels within the 42 sampled stands ranged from 0 to 100 percent (Table 1). Stands were grouped into 12 general locations (fig. 8). The average WPBR infection level on remaining live, mature whitebark pines in the Helena and Lewis & Clark locations in Montana was over 80 percent, and in four other locations the average rust infection was over 60 percent. The Sawtooth and Salmon stands in central Idaho consistently had low average rust infections (0 to16 percent), while infection levels in other areas varied widely. For example, three of four sites in YNP in Wyoming varied from 12 percent to 28 percent while the Mt. Washburn site had an infection level of nearly 43 percent. Similarly, three of four West Gallatin Montana sites had infection levels from 60 to78 percent, but Lightning Lake was only 37 percent. The Sawtooth and Salmon blister rust infection levels were significantly lower ($p<.01$) than most other locations. Blister rust levels at YNP were not statistically different than Salmon or Targhee but were significantly lower than all other locations ($p<.05$).

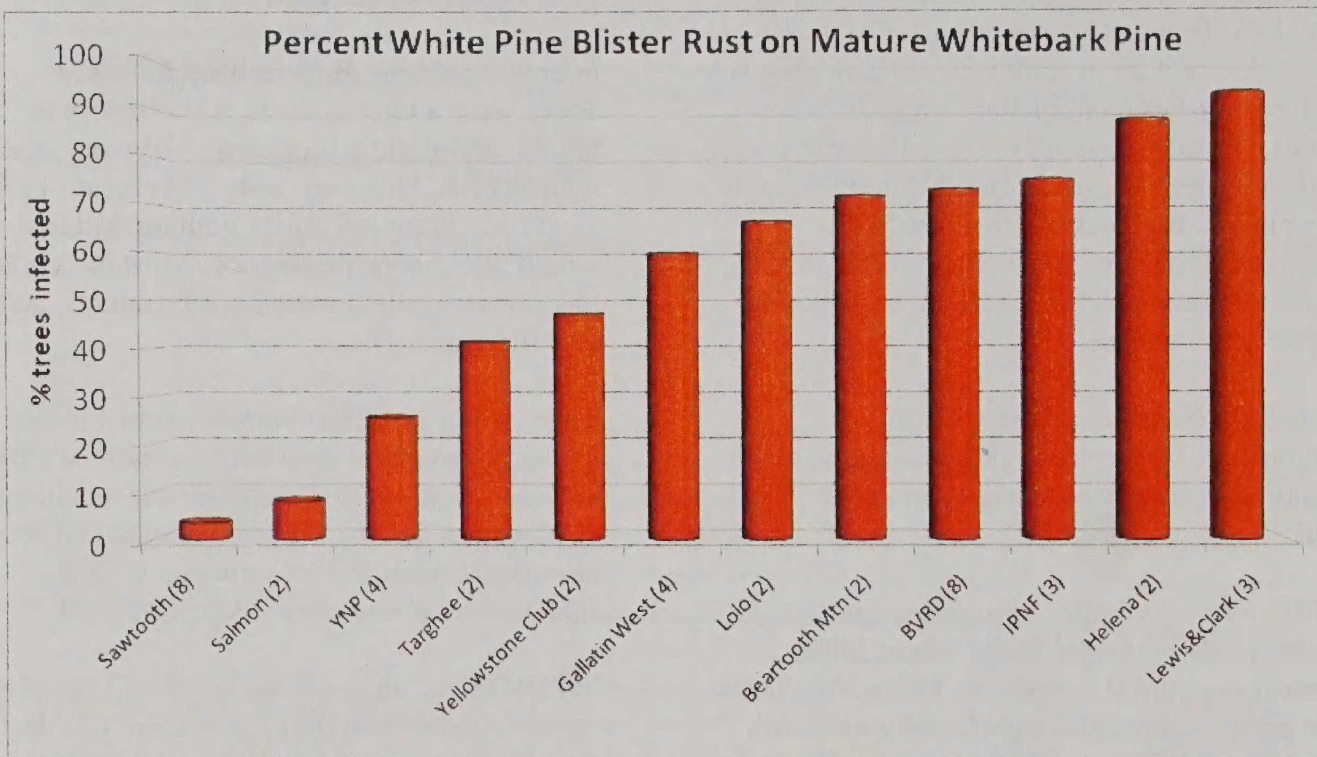

Figure 8. Percent of mature trees infected with white pine blister rust on 12 forests or areas. Number of stands sampled in each area is in parentheses.

Infection on Live Whitebark Regeneration
Only 26 of 42 sites tallied sufficient numbers of whitebark pine regeneration to get an estimate of WPBR infection (table 1) (Only five sites tallied enough regeneration on the 1/300 ac. subplots, the rest were determined by off-plot tallies). Average infection level on these 26 sites was 23 percent and ranged from 0 percent to over 80 percent. The lowest average rust infection levels were in central Idaho (0 to 5.3 percent). Infection levels of regeneration in northern Idaho varied from 15 percent to 23 percent. Those in western Montana ranged from 6.1 percent to 67.9 percent, and those in the GYA varied from 4.2 percent to 80.8 percent.

Competing Vegetation

Mature Tree Species Abundance
The abundance of other mature tree species outnumbered live, mature whitebark pine after MPB outbreaks in 18 of the 42 stands surveyed. This represented 90 percent of sites in northern Idaho and western Montana, 32 percent of sites in the GYA, and 20 percent of sites in central Idaho. Subalpine fir (*Abies lasiocarpa*) was the most abundant mature tree species on 71 percent of sites surveyed followed by lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), and Douglas-fir (*Pseudotsuga menziesii*).

Regeneration
Tree species other than whitebark pine less than five inches in diameter were more prevalent on 28 (69 percent) of the 42 areas surveyed (fig.9). By far, the most abundant other species was subalpine fir (nearly 97 percent of all other species tallied). Other species recorded were Englemann spruce, Douglas-fir, and lodgepole pine. Regeneration per acre of other species varied from 0 percent at Railroad Ridge in the SNRA to 100 percent at Sylvan Lake in YNP. Twenty-three sites had more than 500 TPA of other species, and 13 of these sites had over 1000 TPA of other species. There were 18 stands with more than 500 whitebark pine regeneration TPA, and four of these had more than 1000 TPA. The maximum TPA (3,000) of whitebark pine regeneration was recorded at Edith Lake (Helena NF) in western Montana.

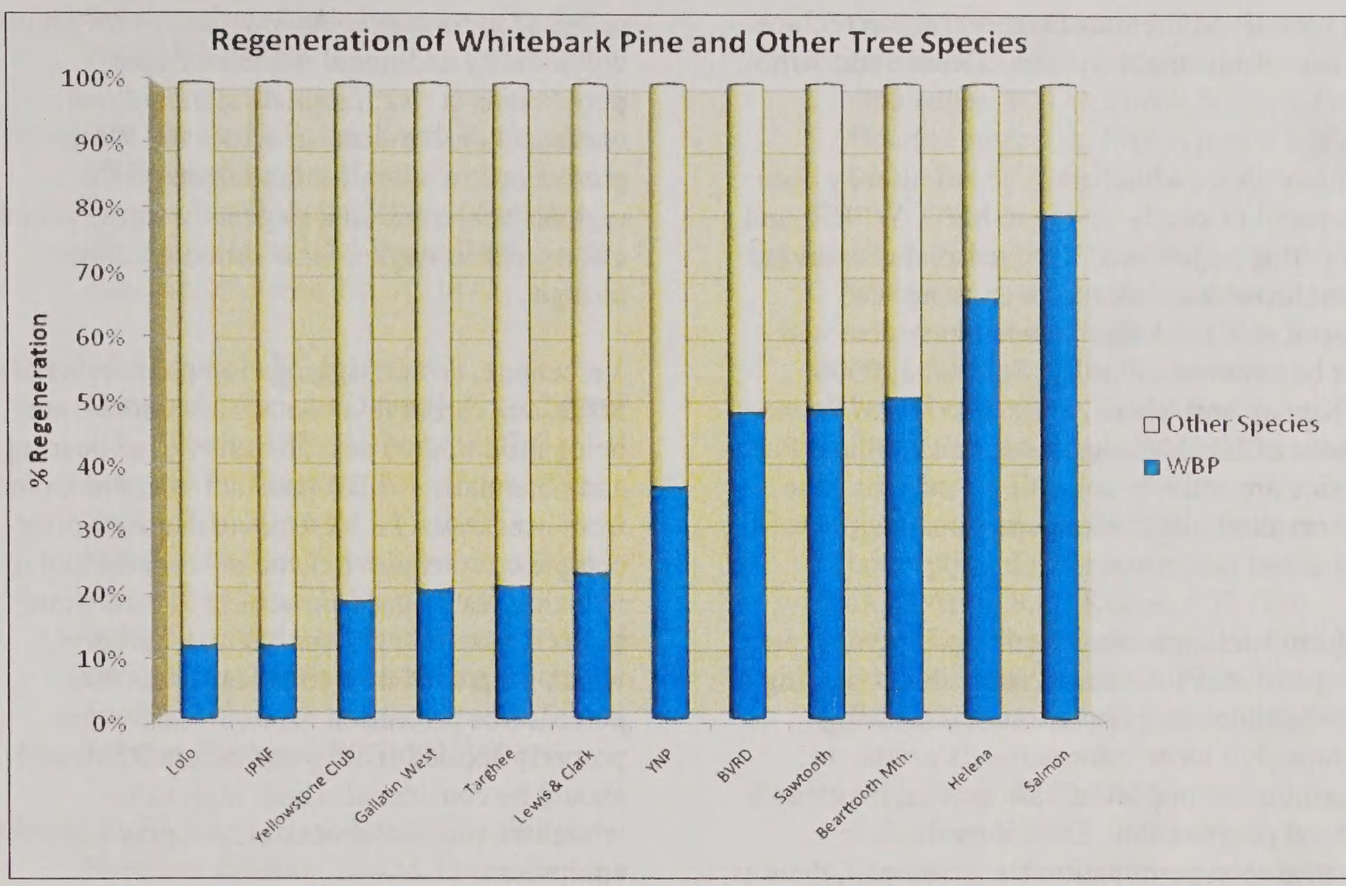

Figure 9. Percent whitebark pine and other tree species regeneration.

DISCUSSION

In order to determine the probable stand-composition trajectory for these whitebark pine sites, we looked at WPBR infection levels, whitebark pine basal area reduction due to MPB, live whitebark pine BA and percent of stand composition, abundance of other mature species, and the abundance and health of all regeneration. Live whitebark pine BA is important for cone production levels needed for seed dispersal by Clark's Nutcracker. Below a threshold level of 22 ft^2 per acre (equivalent to 5 m^2/ha as per McKinney and others 2009) seed dispersal by the bird is disrupted. We defined critical levels based on logical assumptions for the following characteristics (see table 1):

- live whitebark pine basal area remaining < 22 ft^2/acre (tan highlight, table 1)
- whitebark pine BA reduction due to MPB > 90 percent (pink highlight)
- remaining live, mature whitebark pine <50 percent of stand composition (yellow highlight)
- percent WPBR in remaining live mature trees >50 percent (grey highlight)
- percent uninfected whitebark pine regeneration <50 percent total tpa (blue highlight)
- percent WPBR in whitebark pine regeneration >50 percent (green highlight)

Based on these criteria, we found that 24 of 42 of stands surveyed (57 percent) met at least two of these criteria and will likely convert from whitebark pine to other cover types without restoration efforts or wildfire (table 1, purple highlight). Stands that fall into this category should be considered higher priority for active management alternatives that would assist in enhancing whitebark pine restoration.

Restoration Activities
Natural regeneration is closely related to fires that historically removed competing vegetation and created seed beds for nutcracker seed caching activities. Aggressive fire control activities may be impacting these opportunities

and prescribed fire may be necessary to replace the role of historical wildfires (Keane and Arno 2001).

In many areas, whitebark pine has already been extirpated or nearly so due to MPB, WPBR, and competing vegetation. If these isolated areas are more than a few miles from existing seed sources, it is unlikely that whitebark pine will ever be restored naturally (Schwandt, 2006; McKinney and others 2009). The Forest Service, Bureau of Land Management, and National Park Service are actively collecting cones for gene conservation, restoration, and screening for blister rust resistance.

Unfortunately, planting seedlings in remote areas is expensive. Current tests using direct seeding to restore whitebark populations are showing promise, but more information is needed to determine the impact of various seed treatments on seed germination. Even if methods to enhance seed germination are developed, there is a critical need to increase survival of young seedlings. Over 200,000 whitebark pine seedlings grown in nurseries have been recently planted in the western United States. However, survival rates are low in some areas. One possibility for enhancing seedling survival is the application of beneficial mycorrhizal fungi. These fungi enhance survival by providing nutritional benefits, imparting drought tolerance, and offering protection from pathogens and soil invertebrate herbivores (Cripps 2002, 2004). Recent studies in northern Montana and Wyoming have identified over 40 fungi in whitebark pine sites and several promising candidates are currently being tested (Cripps and others 2008, Mohatt and others 2008).

In some areas, competing vegetation is being reduced by prescribed fire or mechanically by thinning or girdling over story species. The success of these treatments is not well known at this time although monitoring plots have been established at some sites.

Additional monitoring is proposed for high elevation, five needle pines that are threatened by insects, disease, and climate change through a Forest Health Monitoring program initiative called *Monitoring on the Margins*. This program will identify additional whitebark pine populations at risk, facilitate standard and consistent data collection across the West, provide information for land managers at a regional scale, and link to genetic conservation efforts and strategies for addressing climate change.

Verbenone, an anti-aggregation pheromone of MPB, and carbaryl, a contact insecticide, are being used to protect high-value, cone bearing, and potentially WPBR resistant whitebark pine from beetle attack. Verbenone does not offer complete protection but can be a useful tool in reducing beetle-caused mortality in the short term (Kegley and Gibson 2009). Carbaryl, which is sprayed on tree boles, offers 100 percent tree protection for two years when properly applied (Fettig and others 2006) and should be considered where high value whitebark pine are accessible to spray equipment.

It is critical that restoration efforts, including cone collections and protection of cone bearing trees, be planned for isolated whitebark pine populations, especially if they are threatened by MPB and WPBR. The results of this study should help prioritize restoration efforts in whitebark pine stands in Idaho, Montana, and Wyoming that are at greatest risk.

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